The Effect of Wave-Induced Caustics on ACOMMS and Buried Objects: SIO Component

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LONG-TERM GOALS

The long-term goal of this research is to understand underwater acoustic communications propagation through the surf zone. A secondary goal was to see if high-intensity, transient sound caustics created by shoaling surf could be exploited to improve the detection of buried objects in the surf zone.

OBJECTIVES

The background to this work come from the surf zone acoustic channel characterization effort undertaken as part of the very shallow water/surf zone mine countermeasures program. Prior channel characterization work had identified the formation of high-energy sound focal regions caused by shoaling surf acting as surface gravity wave lenses. The caustics result in transient, high amplitude arrivals late in the time-varying impulse response arrival structure of the acoustic channel. The arrivals are of sufficient amplitude to disrupt successful communications in very shallow water, and one of the objectives of the present work is to obtain a full characterization of the phenomenon.

A second objective was to determine if the surface-scattered, high-angle caustics could be exploited to improve target backscatter signal-to-noise ratio estimates and thus improve the ability to detect buried objects in the near shore environment.

APPROACH

A short-duration experiment (5 days) was planned to study acoustic channel properties in the surf zone just north of Scripps Pier in collaboration with Dr. James Preisig of the Woods Hole Oceanographic Institute. The experiment configuration consisted of a sound projector with a co-located reference hydrophone and two vertical arrays of hydrophones mounted at 90 m inshore and 90 m cross-shore of the source. The propagation paths were instrumented with 2 arrays of 10 pressure sensors spaced at 10 m intervals to measure the shoaling surface gravity wave field. An autonomous CTD was deployed at the source location to characterize the water salinity and temperature. In addition, an oil-filled, spherical target was supplied by Kerry Commander of CSS, Panama City, Florida to be used as a buried target. Monostatic acoustic arrivals were recorded both with and without the target to investigate the impact of sound focused by gravity waves on the detection of buried objects.

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The two primary acoustic transmission paths were oriented inshore and across-shore to permit characterization of the different focusing properties of the surface gravity wave field when scattering sound aligned with the direction of propagation versus along a wave crest.

A wavefield code has been developed by Dr. Chris Tindle of Auckland University, New Zealand, to model propagation through the surf zone, including transient caustic behavior. To support this study, the approach adopted was to extend the model to handle a penetrable seafloor with variable bathymetry.

WORK COMPLETED

The experiment to characterize transmission through the surf zone was deployed and completed by January, 2002. Despite heavy surf complicating the deployment and destroying 2 pressure arrays, a complete data set of transmissions inshore and across-shore with environmental data were obtained. A series of transmissions with the spherical target buried at various ranges from the receiver array along the inshore propagation path were also taken. Segments of the data set have been analyzed to relate the instantaneous, time-varying sea surface with the observed formation of caustics in the sound field. Clear (and expected) differences were observed in the high intensity arrival structure between the inshore and cross-shore propagation paths. Overall, the effort to characterize caustics over 90 m length scales along inshore and cross-shore paths was successful.

A complete set of transmissions were also taken along the inshore propagation path with a buried spherical target in place. An analysis of the forward scatter and backscatter data for these trials failed to reveal any significant advantage in using transient caustics to detect buried targets. Thus, the outcome of this component of the experiment was a negative result.

The propagation model developed by Dr. Chris Tindle at the Auckland University Physics Department was modified to include the effects of a penetrable seafloor with variable bathymetry and multiple scattering effects at the sea surface. This model has subsequently been used to successfully model the arrival time, amplitude and phase of surface scattered acoustic wavefronts.

RESULTS

The first result from the surf zone channel characterization is that systematic differences can be observed in the arrival structure of high intensity sound scattered from shoaling surf in the along-shore and across-shore directions. These differences are consistent with the hypothesis that gravity wave lenses are the source of the focal regions, and can be explained by the gravity wave structure in the along-shore and across-shore directions.

The second result is that we were unable to exploit the caustics to improve buried object detection.

The third result comes from the analysis of previous field data supported by this program in collaboration with Kerry Commander and co-workers at the Coastal Systems Station, Panama City, Florida. The result relates acoustic channel availability in very shallow water/surf zone region to a single environmental parameter, which is the McCowan breaking criterion. The result is summarized in Figure 1.

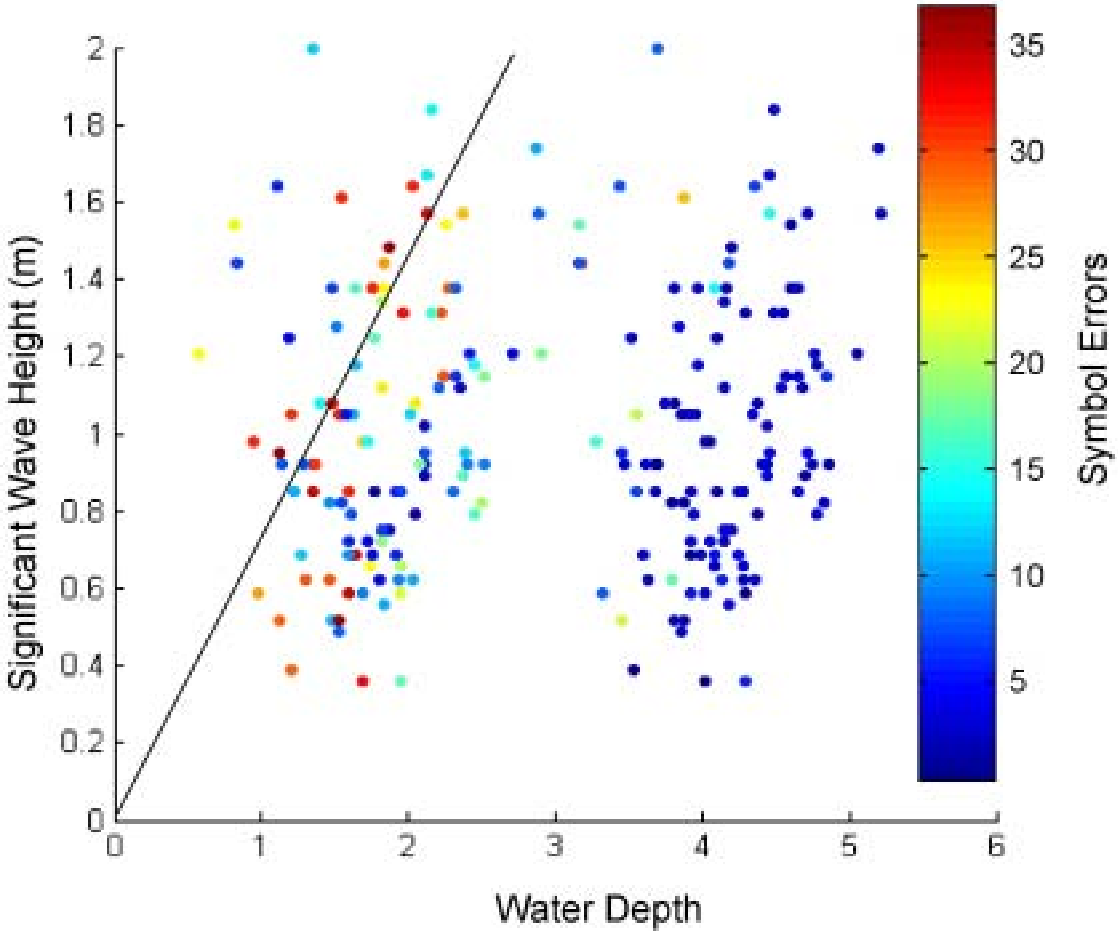

Figure 1. The figure, taken with permission from Commander et. al., shows symbol errors as a function of water depth and significant wave height. The solid line in the figure shows the significant wave height at which wave breaking begins for a given water depth, as established by the McCowan breaking criterion. The data show that communications errors increase in the region predicted by the McCowan breaking criterion.

The symbol errors in Figure 1 were estimated from the measured surf zone channel properties by averaging the symbol errors produced by 125 simulations of a binary phase shift keyed receiver (Commander *et. al.*). The data show a clear increase in transmission errors in the vicinity of the McCowan breaking criterion. Shoaling waves in water depths roughly equal to or less than that determined by this criterion break, injecting large plumes of bubbles into the water column. The bubble clouds formed in this way absorb and scatter sound, effectively blocking the acoustic transmission path. This analysis demonstrates that the McCowan breaking criterion can be used as a first order predictor of the water depth at which acoustic communications will begin to fail for a given significant wave height.

IMPACT/APPLICATIONS

The main application is the potential use of the McCowan breaking criterion as a predictor of communications system performance as a function of water depth for a surface gravity wave field of known RMS wave height.

RELATED PROJECTS

This work is directly linked to the project "The Effect of Wave-Induced Caustics on ACOMMS and Buried Objects: WHOI Component" being run by Dr. James Preisig of the Woohs Hole Oceanographical Institution. Dr. Preisig and I are continuing to collobrate on the modeling and analysis of data taken from this program to understand and optimize underwater acoustic communications in the very near shore region and the surf zone.

REFERENCES

Kerry W. Commander, Robert J. McDonald, Grant. B. Deane, Dale Green, and John S. Stroud, "The effects of environmental variations in the shallow water acoustic channel," *in preparation*.